Storing, distribution and blending of biodiesel

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Abstract: Due to the nature of biodiesel fuel (B100) as well as biodiesel and fossil diesel oil blends, these fuels demand specific conditions of storage, handling, transportation, and distribution. Although it is necessary to pay attention to each of the elements in the distribution chain, the most critical operations are related to storing. Tanks for biodiesel storing have a dominant influence on the maintenance of stable quality, as may occur, issues that directly affect the degradation in quality and problems during distribution, blending, and use. In the designing process of the tank space and the installations must be considered all specificities of biodiesel also that materials are resistant to the influence of biodiesel and do not affect its contamination. Particular specifics related to the stocking and blending are the problems that can occur in the winter, due to relatively poor low-temperature properties of biodiesel and their blends. This paper is focusing on these problems.

Keywords: FAME, aging, storing, blending

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1 Introduction

In the biodiesel distribution chain, tanks are the most complex element for construction also maintenance. Selecting the wrong material for its construction can cause a long-term problem in its exploitation, with direct implication on the final fuel quality. The same material criteria also relate to the distribution network.

Disadvantages in the tank farm are often manifested by restrictions on the manipulation and deterioration of biodiesel quality. Storing of biodiesel fuel due to stagnation, can cause deposits consequently filtration dirt, vehicle discharges, and other corrosion-fueled fuel systems. Various disadvantages related to agitation, heating, seepage, inadequate use of materials and drainage as well as disregard of "good management" during warehousing and distribution will only increase operational problems, resulting in increased costs over a longer period. The blending of biodiesel and fossil diesel can be done in a variety of ways, depending on a whole range of factors: availability of installations, percentage of biodiesel in the blend, outdoor temperatures, etc.

2 Tanks for storage of biodiesel

Storage tanks due to different criteria can be divided. Based on

- Purpose, to storage of biodiesel B100, or mix,
- Functionality, to primary, or secondary terminals
- Type of underground, or overhead
- or are too new or reconstructed-existing tanks

Due to a variety of different parameters that could affect affecting the construction of tanks, very often tanks don't meet all necessary conditions needed for flexible

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manipulation, and the absolute inability for contamination or problems in winter conditions. Being in mind all this, it is necessary to observe all limitations in the tank space and be aware of possible problems in use. If new tanks will be constructed it is necessary to look at all the parameters related to the tank area construction and try to reduce the number of possible restrictions.

3 Types of tanks

There are two basic types of tanks: underground and aboveground. If new tanks are being built for storing small quantities of fluids, underground tanks are a good choice because they are suitable to avoid external temperature dilations.

Aboveground tanks should be isolated, sheltered from direct sunlight, and painted in reflective color. The basic postulate in the construction of new ones is that they need to be inert to temperature drifts since low temperatures cause problems in quality, blending, and distribution because of the poorer low-temperature characteristics of biodiesel. High temperature during storage accelerates biodiesel fuel degradation.

3.1 Recommended materials for storages and distribution systems

Most equipment designed for diesel fuel tank farm can also be used for storing B100 but during the selection of the material for tank space and/or distribution systems it is necessarily aware of several issues: fatty acid methyl esters (FAME) chemical properties, chemical composition differences about fossil fuel, as well as specificities related to chemical functionality. Due to this chemical specificity, the different components in the fuel distribution system may be less compatible with FAME (B100) compared to pure fossil fuel. Some components, after longer exposure, can accelerate degradation reactions of individual elements in tanks and distribution systems.

Acceptable materials for the production of tanks are aluminum, steel, fluorescent polyethylene and polypropylene, Teflon, and most fiber glasses. On the other hand, if tanks will be made of brass, bronze, copper, lead, tin and zinc storage of B100 can accelerate the oxidation of diesel and biodiesel fuel, can result in the formation of insoluble components in the fuel (sediments), gels or salts, if reaction with some fuel components occurs (US Department of Energy, 2006).

Leaded lemons and zinc coatings should also be avoided, as well as copper pipes, brass reinforcement, and copper seals. In these cases, fuel or tanks tend to change color while residues tend to ignite fuel filters. Such equipment should be replaced by stainless steel, carbon steel, or aluminum.

The basic non-integrity of tanks and/or distribution systems for petroleum products and biodiesel is that B100 penetrates some plastics that are commonly used as parts of the plant equipment in installations for oil refining and production of petroleum products. Frequently used materials such as polyethylene and polypropylene should not be used for storing the B100.

As a distributor and sealant material, biodiesel compatible sealants and elastomeric materials are recommended as B100 can degrade certain creams, elastic gaskets, butterflies, and plastics due to prolonged exposure. Particularly natural or Nitrile rubber compounds, polypropylene, polyvinyl, and Tygon materials are sensitive to deformations. A whole series of tests are currently being carried out to expand the list of non-stick materials.

In some cases, it is necessary to specify the precise chemical composition of biodiesel (methyl esters of fat and oil), information, or even the exact chemical name of some biodiesel components such as methyl oleate, methyl linoleate, and methyl palmitate or methyl stearate.

By reducing the amount of biodiesel in the blend, its impact on the material is reduced. At low biodiesel content (B2), no adverse effects do exist, so it is sufficient for tracking the crevice and sealant, the leak.

3.2 Storage conditions

FAME (B100) should be stored at a temperature of at least 6°C higher than the blur temperature. Most underground tanks are adequate, but in the case of aboveground tanks, depending on the climate, the tanks should be isolated, have the ability for mixing and heating. These precautionary measures are also applicable to pipelines, pumps, and tank trucks used for transportation. Heating can be achieved with any of the usual heating methods but should be designed to minimize the number of overturning points and prolonged exposure to FAME at high temperatures.

If the temperature does not decrease and the crystals begin to precipitate and need to be melted by heating the fuel, although residual mono-glycerides and sterol glucosides (SG) are difficult to dissolve again (Lee et al., 2007). This process can be slow, however, especially if the fuel is heated very slowly or just on the tank rim. Crystals formed in FAME or a mixture of diesel can be deposited at the bottom of the tank and to form a gel layer.

Slow stirring can prevent the "building" of crystals at the bottom of the tank. If the FAME product completely changes to the gelatin phase it is advisable to raise the temperature to 40°C-60°C and melt most of the saturated FAME components, especially if FAME is to be used immediately. If there is enough time, lower heating temperatures can be used for FAME to reach its equilibrium cloud point.

In colder seasons, the B100 sometimes coexists with a low fuel dew point diesel to prevent crystallization. Such a blend has to be prepared in advance before it comes into diesel fuel. Recommendations for FAME also applied to diesel mixtures.

Although some data suggest that more stable types of FAME can be stored for a year or more, it is generally recommended to be limited to a maximum of six months. Essentially, the diesel mixtures have a longer duration of B100, depending on the type of FAME and blended additives. Even if a diesel blend is stored, the recommended maximum storage time is also no more than 6 months.

In practice, FAME trade should be faster because it suffers "aging" in the warehouse, increases the acidity, increases viscosity, and can also form different types of deposits (gums, varnish). For FAME quality monitoring during storing, indicators that should be determined are oxidation stability, acid number, viscosity, water, and sediment content. All these indicators can be used as indicators for whether FAME complies with EN 14214 or not (CEN, 2007; US National Biodiesel Board, 2007b; Elliott, 2007).

"Good practice" of fuel inventory management (first in—first out) and frequent product turnover should minimize stability concerns for most applications, biodiesel, and fossil diesel blend with biodiesel.

As the fuel level in the tank decreases, the air enters through the air valve and comes into contact with the fuel. Excess air that is drawn into the reservoir can lead to higher oxidation, particle pollution, and increased water levels. These pollutants will affect FAME quality. To limit the influence of air in the reservoirs, it is recommended that FAME and diesel mixtures are not stored for a longer period in partially empty tanks without the use of oxidant stability additives.

3.3 Contamination during storage

Biodiesel is susceptible to problems caused by water contamination. It is recommended to install a desiccant filter on all gauges as this will greatly reduce water condensation in the tank. It is recommended to install drainage valves and shafts on the tank, in practical and low positions. Both free and dissolved water accelerates corrosion and fuel degradation.

Free water can enter in the fuel tank by condensing, through the fuel distribution system, by flowing through the filling or measuring valve, over drainage valves or piping. In addition to initiating an acceleration of fuel degradation, water provides a suitable microbial growth environment.

Microbiological activity, surface, alcohols, particles, and poorly designed additives can be the cause of problems with water contamination. Poor tank design can almost completely prevent removal of the free water being if it is present, so it is important to take steps to prevent water penetration into the fuel tank.

A preferred approach to microbiological contamination prevention is the "host approach" program being handled with tank space. However, if there were any microbiological problems, shock-therapy with biocides could only be used as a temporary measure after the removal of complete water and contamination. Accordingly, the details related to the current practice need to reexamine and modified as needed to avoid re-problems.

Continuous application of the biocides does not prevent the entrance of water into the system and therefore it is not a suitable preventative measure against water problems. Regular use of the biocide can even increase the resistance of microorganisms to treatment and has some disadvantages that can and must be adequately overregulated. For example, biocides are toxic chemicals and generate bio-muds that need to be removed immediately. The regulations often limit the biocide tolerance, and the water from the tanks treated with biocides has to be disposed of as chemical waste

3.4 Maintenance of tank farm

Continuous, systematic maintenance of fuel tanks and distribution systems is the key element to prevent problems. Monitoring, removal of water from the fuel system is the best preventive measure that can be taken. Over time, operational problems can arise due to the accumulation of corrosion and sediment contamination and pollute diesel fuel systems. The presence of free water can promote corrosion of the fuel system also microbial growth.

Microbes live in the interlayer between fuel and free water. Since the introduction of ULSD (Ultra-low-sulfur diesel), microbial contamination in diesel fuel has become a more common problem. In the mixes of biodiesel and diesel fuel, and the presence of free water, there is an increasing tendency towards microbial growth. It is recommended that the tanks have filters installed to eliminate the possibility of contamination of the vehicle fuel system (US National Biodiesel Board, 2007a)

To ensure that pollutants do not generate fuel quality issues, it is important to remove them before they are accumulative. It is important to note that each fuel tank farm and distribution system has potential problems, so frequent contamination checks are required.

Lack of attention to water drainage in the systems can initiate all problems related to storing and subsequent fuel exploitation. In the case of a good grip on the system, a lifetime of biodegradable waste is extended, without degradation of quality. Fuel testing in the tank, related to microbiological contamination, is recommended twice a year, possibly in the autumn and spring (Nazzaro and Porter, 2005).

If pollution is detected, it must be removed as soon as possible. Water should be drained if the truck tank is equipped with a drainage installation or with a mobile installation- truck equipped with a vacuum pump. Whatever method is used, removal should be done at the same time as slow as possible, so that water can freely sink into the low points on the reservoir floor. A visual inspection of water and fuel should be done, and the process of draining the fuel should last until the fuel becomes clean and airy.

In case of the identification of the deposits in the tank, it is necessary to clean the tank. The most efficient cleaning method is with a tank truck, equipped with a vacuum pump, which sucks the mud. At higher levels of contamination, more efficient cleaning methods are needed: high-pressure pump cleaning or physical scrubbing of the tank interior (NREL, 2009).

4 Storing of FAME in refineries and terminals

To ensure that the biodiesel distribution infrastructure is sustainable and efficient, such infrastructure must ensure obtaining and maintenance an obtained quality of products. Supporting the growth of market demands, needs's a distribution of biodiesel on a larger scale, more efficiently and at lower costs - ideally by existing infrastructure for oil derivates.

Using the same distribution network for biodiesel and petroleum products implies consideration of the similarity of these fuel characteristics, their differences, the specific function of biodiesel as the solvent, and possible problems related to its use in cold weather conditions. Successful integration of biofuels into the common infrastructure requires that the declared specifications must be maintained at all stages of storing, blending, and transport. Because of the specificity of the quality, there are some requirements that the distribution network needs to meet - especially for the B100.

4.1 Distribution network

The basic partition of the distribution terminals is based on use is on primary and secondary. It usually determines the method of blending and storage strategy, since the primary (production terminals) are mostly better equipped. Generally, we can say that the primary terminals are characterized by in-line blending and for secondary (distributive); in-tank, and splash technique of blending.

Usually, in the primary terminals, located in the refineries, fossil fuel tanks are used for biodiesel storing. They must be insulated, equipped with a mixer, or a recirculation system (for stirring), as well as blanketing system. At secondary distribution terminals, tanks may not have any of these elements, which determine the way of manipulation.

At the primary terminals for petroleum products distillates are usually stored in large aboveground tanks. Although most of the terminals have the required capacity and heating equipment, only the storage of certain distillates requires this equipment. The primary terminals have equipment for delivery and loading of the products, different kind of equipment depending on terminals. For example, for terminals connected to product lines, it is not necessary to have terminals for other types of transport (train or truck).

Finally, given that the primary terminals are designed to provide downstream distribution of finished products, they all have loading capacities for transport by tankers, pipelines or railways. Some existing terminals can have the quality injecting equipment on loading ramps.

However, in most cases, the existing equipment to a limited range can be used for the blending of additives to fresh biodiesel and biodiesel blends. Some of the primary terminals may also have equipment that facilitates the blending of the product, while such equipment could be added subsequently (e.g. In-line equipment for biodiesel blending).

In downstream distribution, products are delivered from primary terminals: product lines, rail tanks, truck tanks, or tankers. Sometimes, finished products can be delivered to the truck tanks directly from the primary terminals to retail facilities or to end users without passing through the secondary terminals.

Secondary terminals and warehouses can be modest objects with several aboveground tanks, with the possibility of storing just a broad range of "white" products (gasoline and diesel). There are larger sized secondary terminals, which can have small and/or large tanks (above ground or underground) and offer a full range of "white" products.

4.2 Blending of biodiesel

During the process of biodiesel blending, it is necessary to adapt the existing infrastructure. For first it is important to choose the blending option that best meets the needs with the maximum possible use of the existing equipment. Due to the specificity of different biodiesel blends, it is not good to choose the same stirring method for a complete range - from B2 to B100.

Blending installation should be a combination of partial utilization of the existing infrastructure, with the construction of additional installations. The equipment needs to be embedded with minimal budget spent on the reconstruction of the distribution facility.

A blending of FAME with hydrocarbons or diesel can be performed at the refineries or terminal locations. Since refineries are usually better equipped with fuel quality testing equipment, necessary to optimize mix composition, this location is more desirable for performing the blending operation.

Blending on terminals is also acceptable. However, for fuel quality assurance, quality assurance procedures are more impractical and durable. FAME is fully compatible with diesel, so the blending of FAME is not complex. Regardless of blending strategies, it is important to understand some of the significant FAME features that may affect blending processes.

FAME has a higher density (~ 0.88 to 0.84 kg L^{-1}) and higher viscosity (max. 5 ~ to 4 mm^2 s^{-1} at 40°C) compared to EN 590 (2009) diesel fuel. Precautionary measures should be taken to ensure a homogeneous mixture. If components are added to the reservoir properly FAME should not be the first or last component. That is an important measure to avoid the formation of a non-blended bottom layer.

FAME also has a cloud point than EN 590 (2009) diesel. If different components are added to the blending tank, then temperatures of all components should be above the cloud point of the FAME point, which will provide a safe flow and prevention of the formation of sludges that can't be easily resolved again. Several different strategies can be used to achieve proper blending: blending in the tank, in-line blending on tank filling line, in-line blending on the collector system, loading ramps, gradual addition of spraying components or sequential mixing (NREL, 2009).

a. Blending in the tank, Splash blending**:** The required quantities of FAME and diesel fuel are pumped separately into the tank and stirred properly in the tank or by the internal circulation of tank contents.

With this blending technique, it is important to consider that biodiesel to have higher specific gravity than diesel, as previously stated. The biodiesel has a specific density of 0.88 kg L^{-1} compared to 0.85 kg L^{-1} as much as diesel has. The basis of this blending technique is that the biodiesel should be "sprayed" at the top of the layer of fossil diesel already loaded into the tank. If this order is not respected, fuel cannot be properly blended.

b. In-line mixing at tank filling line**:** FAME and other components are concurrently pumped and merged into the filling line with flow control and filled to a common tank. The turbulence conditions on the merging line of the different components and in the line promote mixing, but besides that, the use of a static mixer is also recommended. In this case, blending should not be made in the tank.

c. In-line blending on the loading ramp**:** FAME is continually injected into the diesel fuel line. This can be done during the process of the tank truck loading along with flow control. Alternatively, FAME can be added with a small flow or pulse rate overtime during the filling of the tank truck. This procedure is similar to the method of adding additives that are dipped in diesel on the loading ramp.

d. Sequential blending**:** This is an operation in which FAME and diesel fuel are sequentially loaded into a truck tank or other means of transportation. In this case, there is relatively little fuel mixing during the loading into the truck tank. Once the fuel is loaded into the truck tank, during transport, on the road, the fuel is mixed and sometimes considered as sufficient. This blending strategy is not recommended because there is a risk that the product will not be homogeneous when the vehicle arrives at the destination, especially in the winter when the low temperature is low.

The FAME blending recommendations received in the refineries are also valid for blending at terminals. The quality of fossil diesel fuel should be such that the diesel blend after the addition of FAME complies with the EN 590 specification (2009), as discussed above. If blending is based on volume/flow control, without analytical laboratory methods will have implications on blending procedures and setting boundaries related to critical properties of diesel fuel. Besides, precautionary measures should be taken to ensure a homogeneous blend.

5 Conclusion

Biodiesel due to its nature is subjected to degradation and requires specific conditions for storing, distribution, and blending with fossil diesel. Disadvantages in the storage area are reflected in the deterioration of its physical-chemical characteristics and the problems in exploitation.

The basic prerequisites for adequate storing are a suitable temperature (at least 6°C above the cloud temperature), shorter storage time, minimal space in the tanks, and removal of water and air contamination.

Proper construction materials (aluminum, steel, fluorescent polyethylene and polypropylene, Teflon, and most fiberglass) due to their solvent properties should be used for the tanks and installations.

When blending biodiesel and diesel fossil fuels, differences in viscosity and density relative to diesel fossil-origin should be considered.

Fossil digestion techniques can be grouped as blending techniques in the tank (splash blending), in-line blending at tank filling line, and sequential blending techniques when loading into a means of transport. In all these techniques, loading order is important and observing all procedures because, in the case of non-compliance any of the steps, the obtained blend will do meet the requirements of homogeneity.

A special problem is storing and blending in winter conditions as the storage temperature should be 15°C higher than the cloud point, which means that the tanks must be equipped with the appropriate heat-sealing and stirring equipment.

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