BEST
BioEthanol for Sustainable Transport

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Short report from the Swedish experience of using low blend of ethanol derivative in diesel, ED-diesel

Short report on the introduction of E-diesel

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General description of low blends in diesel

Within the BEST project, low blends in diesel are studied. Low blends of ethanol or ethanol related products in diesel are generally called E-diesel. In this study, two categories of E-diesel are tested. The fuel that is tested by BioFuel Region and SEKAB is a blend of 10 percent Ethanol Derivative and 90 percent diesel. To distinguish this fuel from the low blend tested at the other sites, the BFR low blend is called ED-diesel.
Site Rotterdam is testing a classic E-diesel, which is a mixture of pure ethanol and diesel. The fuel composition is 7,7 percent ethanol and up to one percent of a solubilizer additive to provide a clear homogenous and stable fuel.

All diesel qualities are compatible with the E-diesel blends. Ultra-low sulphur diesel, Diesel Mk1, European EN590 and biodiesel.

All kind of low blends in diesel can be used as fuel in a standard diesel engine, without any modifications of engine, injection pumps, fuel system and exhaust after treatment equipments et cetera. The E-diesel fuels can also be used in the existing transport and distribution infrastructure and delivered to customers at existing filling stations.

Diesohol

The first successful low blend in diesel, called Diesohol, is a fuel containing alcohol that comprises a blend of 84,5 percent diesel, 15 percent hydrated ethanol and 0,5 percent of an emulsifier. The fuel is a milky emulsion containing small particulate drops of ethanol in the diesel. The emulsifier additive is an important component in the preparation of the fuel. It has been developed in Australia by APACE Research and has been under trial in Australia for more than twenty years. Demonstration tests have also been performed in Thailand, Chile, Malawi, Germany, Brazil and in Sweden from 1993 to 1997.

The problems of using Diesohol, except from handle the emulsifier additive, which is a very toxic product, is the energy demanding mixing process to make a stable emulsion and the poor blend stability, especially at low temperature. Material compatibility of pump seals and some nitirle rubber seals used in the fuel injection systems of a vehicle is still a concern as well.

E-diesel

In the 1990s the first real tests where made using the present E-diesel technology. E-diesel is unlike Diesohol a mixture of anhydrous ethanol and a solubilizer additive, which makes a clear fuel solution. This ethanol-diesel blend is “splash blendable”, which means that ethanol together with the additive mix very easy with the diesel oil.
The most tested compositions of E-diesel include ethanol blends of 7,7 to 15 percent and up to 5 percent of special additives that prevent the ethanol and diesel from separating at low temperatures or if water contamination occurs.

The solubilizer additive is very easy to handle and not toxic in comparison to the emulsifier additive, but E-diesel also have some disadvantages in commercial use. The fuel is stable at low temperatures but has showed some problem when the temperature goes up, especially when the environment is warm and humid. Then the anhydrous ethanol has a tendency to take up water and cause separation.

E-diesel has been tested and evaluated in full-scale tests by several companies. Among them are O2-diesel, Cummins, Pure Energy, Akzo Nobel.

Facts about low blend of ethanol in diesel

- Demonstrations have so far been conducted in heavy-duty trucks, buses, and farm machinery.
- Use of ethanol changes the vapour lock characteristics of the fuel, which could cause unintentional engine failure.

- All blends of ethanol in diesel decrease the flash point of the fuel from 55-60 °C down to about 12 °C.
- Low blends of ethanol in diesel must be handle and storage similar to petrol.
- The fuels decrease the dependency on fossil fuel and reduce carbon dioxide emissions (CO_2).
- Emission tests have shown reduction in particulate matters (PM), carbon oxide (CO) and nitrogen oxides (NOx).

The main obstacles to fully accept low blend of ethanol in diesel as a commercial fuel are the reduced flash point and the stability problems in comparison to standard diesel.
Therefore, appropriate measures need to be implemented to meet the storage, handling and dispensing requirements that are stipulated for the ethanol-diesel blends. These measures may also include the fitting of flame arresters on fuel tanks.

To fully establish low blend of ethanol in diesel as a commercial fuel the authorities have to give approval to use the fuel and an establishment of an ethanol-diesel fuel standard. In Europe, France is the first country to give approval to use E-diesel.

Swedish experience of using ED-diesel (D3.03)

Instead of using pure ethanol in fuel blends, other components like different derivatives have been tested. In chemistry, a derivative is a compound that is formed from a similar compound or a compound that can be imagined to arise from another compound, if one atom is replaced with another atom or group of atoms.

The idea of investigate the possibilities of using low blend of ethanol derivatives in diesel, came from an old engine manufacture patent that expired in the 1990s. The patent shows that different kind of alcohol derivatives can be used as diesel fuel or blended into diesel, so-called ED-diesel.

Among the advantages using ethanol derivatives in low blends, is that it solves very easy in standard diesel fuel without any extra additives. Up to 50 percent can be solved in diesel without separation, even if water is leaking into the fuel blend. This is because ethanol derivative has a high tolerance to water contamination.

The Swedish part of the low blends in diesel does only include low blend of ethanol derivatives, ED-diesel.

Fuel properties

Except from extremely higher fuel stability compared to ethanol-diesel blends, ED-diesel also have higher flash point, which makes it possible to handle the fuel as same as diesel. In table 1 below, the specifications of ED-diesel is listed in comparison to the Swedish standard diesel Mk1. The composition of the tested ED-diesel fuel is 10 percent ethanol derivative and 90 percent diesel Mk1.

The reason why a blend of 10 percent was chosen depends on two reasons. The ethanol derivative has lower energy density compared to diesel. Tests have shown that a blend with more than 15 percent of ethanol derivative or ethanol reduces the engine power too much. Ten percent has shown to be an acceptable compromise, see table 2. The second reason why not use more than 10 percent of ethanol derivative is the flash point.

Specification	ED-diesel	Diesel Mk1
Cetane number	51	Min 51
Viscosity, 40°C (cSt)	1,6	1,4 - 4,0
Density, 15°C (kg/m3)	815	800 - 820
Flash point (°C)	32	Min 55
Cloud point (°C)	-40	Max -16
CFPP (filter), (°C)	<-35	Max -32
Corrosion, cupper	1A	1A
HFRR (lubricity), (µm)	357	Max 460

Table 1.

The flash point of ED-diesel using 10 percent ethanol derivative is 32°C. According to the Swedish fire risk classification, ED-diesel then belongs to Class 2b. That means it is possible for vehicles to refuel ED-diesel indoors as long as the ambient temperature is below 27°C. If the amount of ethanol derivative should be 13 percent or more, the flash point of the ED-diesel blend will fall below 32°C. Then the fuel has to be handled as petrol. However, the fire risk classifications may differ in different countries. There is no international standard.

Other fuel properties of consequence are lubricity, corrosion and cetane number. ED-diesel fulfils all those three specifications according to both Swedish Mk1 diesel and the European diesel standard EN590.

Introductory bench tests

The first introductory emission study was made in a bench test 2003. The test was made by SEKAB at STT Emtec in Sundsvall, Sweden. STT Emtec's Engine Test Centre is accredited by Swedac according to the quality standard, general requirements for the competence of testing and calibration laboratories, ISO/IEC 17025.

The accreditation covers emission measurements as described by the European directives for R49, ESC, ETC and ELR tests as well as engine power rating tests according to the European 80/1269/EEC directive.

The test engine was a Volvo 7 litre, Euro 2 engine. The engine had no catalyst or other after treatments connected to the exhaust pipe. The emission test result, diagram 1, was made with Swedish diesel Mk1 as a reference fuel.

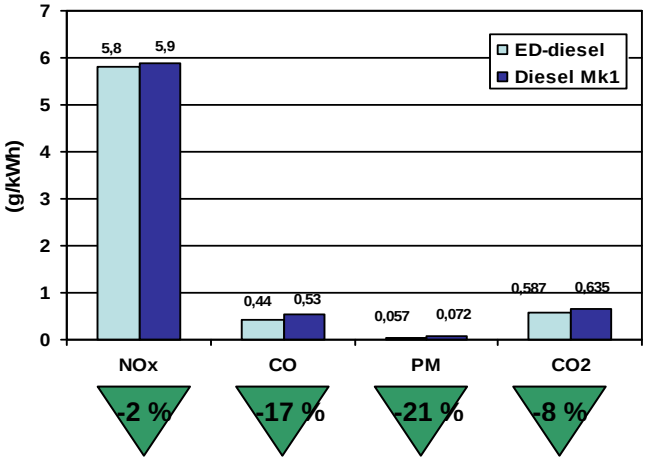

Diagram 1. Emissions measured by European Steady Cycle, ESC.

The emission test showed a very optimistic result. Particulates were reduced by 21 percent, CO reduced with 17 percent and NOx reduced with 2 percent. Calculated from the fuel consumption, the test also showed a reduction in fossil carbon dioxide (CO_2) with 8 percent.

	ED-diesel	Diesel Mk1	Diff.
Engine power	**212 kW**	**220 kW**	**-3,6 %**
Energy density	**34,1 MJ/l**	**35,2 MJ/l**	**-3,1 %**
Fuel consumption	**0,254 g/kWh**	**0,247 g/kWh**	**2,8 %**

Table 2.

Because of about 3 percent less energy density in ED-diesel the fuel consumption increased with almost the same number.

To confirm this introductory bench test, emission test will be made on the same type of engines, which are in the test buses. They are Scania 9 litre Euro 3 engines. The test is planned to be made in December 2007 and will be evaluated during the first quarter of 2008.

Preparation of full scale test

During 2006 the detailed plan was made to perform a full scale demonstration test on ED-diesel. Contacts were taken with a number of fleet owners to discuss their interest to participate. It was bus companies, bus operators, truck owners and engine manufacturers. End of 2006 SEKAB signed an agreement with the bus company Veolia Transport AB. They have an open interest in renewable fuels and were very interested to test a new kind of low blended diesel fuel.

The buses

Veolia decided to let two of the diesel buses in Örnsköldsvik participate in the test. The buses are standard Scania Omni-city Euro 3 buses. They operate in the regular public transport in Örnsköldsvik. The average mileage for each bus is 70 000 – 80 000 kilometres and the demonstration test was planned to run for twelve months.

Veolia have their bus depot in the centre of Örnsköldsvik where they also have their fuel pumps. Normally they only operate with ethanol buses and a few diesel buses. At the depot they have one ethanol pump and one diesel pump. For this test a separate fuel tank and pump had to be installed.

Before the buses changed to ED-diesel a sample of the old motor oil was taken and new fresh motor oil was filled in both buses. The old oil filter was changed after a few hundred kilometres on ED-diesel, because it was expected that some deposits could be dissolved and clog the new filters during the first kilometres.

The fuel and the fuel tank installation

Because SEKAB so far, have no production of the ethanol derivative, this product was imported from a Chinese producer. The product was delivered in 200 litres drums, which is stored in a container at the SEKAB site. The diesel quality used for this demonstration test is Preem Diesel 5 % FAME Mk1. This fuel quality has 5 percent of Rape Methyl Ester, RME. Including 10 percent of the ethanol derivative, the total amount of renewable fuel is 15 percent. The fuel trade name is Etamix D3.

The blend of the fuel and the distribution to the fuel tank at the depot was quit easy to arrange. Since the ED-diesel blend mix very easy, the ethanol derivative can be added to the diesel and circulated for some time.

SEKAB set up an agreement with the oil company Preem to deliver the ED-diesel to the bus depot. The fuel tank at the depot takes 15 000 litres. Every delivery is about 10 000 litres.

When a delivery take place, the diesel truck arrive at the SEKAB site, filled with 9 000 litres of diesel. One thousand litres of ethanol derivative is then pumped into the diesel truck. The blend is circulated between two boxes in the tank and then the diesel truck drive to the bus depot, about five kilometres from SEKAB. Before the fuel is pumped to the tank, a reference sample is taken.

Experiences from the present demonstration fleet test

Every time the buses refuel, the mileage and the volume of ED-diesel are logged in a computer. That gives an exactly information of the fuel consumption. So far, after six months the buses have an average fuel consumption of 39,2 litres per 100 km. That is the same fuel consumption as running on diesel the same period the year before. That was not expected, since the result from the bench test showed increased fuel consumption at about 3 percent.

Drivability

The two buses started to run on ED-diesel end of May 2007. The change of fuel was made without any problem and until November, after six months, there has not been any standstill in operation depending on the fuel. The buses have been available 100 percent and followed to the original timetable.

The result from the bench test showed loss in engine power with 3,6 percent, which was expected because of less energy density in ED-diesel. However, some drivers said spontaneously that they could feel the same power and the same response from the engine or even better. But this has to be verified in a new engine bench test, since the demonstration fuel has not the same specification due to the extra 5 percent of RME.

Handling of fuel

There have been some complaints from the drivers and some passengers about the smell from the fuel. The fuel has a character of smell that is the same as ether, which can be very irritating. The problem with smell is specially when refuelling and at the bus-stop. Some bus drivers and people who are mixing and supplying the fuel have also felt sick from the smell.

The reason why the ED-diesel fuel composition smells, is because of the ethanol derivative in the blend. ED-diesel has no ethanol or alcohol in the blend but 10 percent ethanol derivative. The derivative chemical product has a very strong irritating and characteristic smell.

There has been lot of internal discussions how this problem should be handled and if there is some possibility to disguise the smell by adding some other component. So far no solution is found. Measures have also been made at the buses and the dispenser to minimise the smelling problem. If this is enough we do not know yet. It has to be evaluated at the end of the test.

So far this is a very serious problem to overcome before this kind of fuel could be used commercially.

Introduction of E-diesel (D3.06)

Within the BEST-project, two sites have decided to perform a demonstration and evaluation test on E-diesel.
In Rotterdam, there has been about one year delay. The original plan of testing E-diesel in both garbage trucks and small inland vessels was changed in late of 2007, because the transport company retreated from the project. The Rotterdam public transport operator RET has now instead joined and will test E-diesel in twelve city buses. The E-diesel demonstration test is expected to start during the first quarter 2008.

La Spezia has due to serious discussions regarding the safety issues taken a very late decision to proceed with the project. The project group has had a meeting with the local Transport Ministry Office. They will suggest the best way to obtain the authorization for the experimentation. A permission to test E-diesel is expected within the next coming months. The plan is to start the test in June, 2008 and run for six months.

Fuel properties

Both Rotterdam and La Spezia will use the E-diesel concept that is developed by O2Diesel.

The general fuel properties are described above. The fuel used in this project is a blend of about 8 percent ethanol and one percent additive mixed into standard diesel EN590.

In comparison to ED-diesel there is no problem with smell when using ethanol. Neither ethanol nor the additive package has any strong or annoying smell in E-diesel.

Preparation for fleet test

Participants Rotterdam site

The Rotterdam site work together with TNO, which is their partner in the BEST-project. TNO Science and Industry is an engineering company, which provide services in many areas aimed at industry, suppliers, and government and R&D organisations. TNO's expertise covers the whole process: design, engineering, planning, processing techniques and the management of the manufacturing process. TNO is also a specialist service provider to the international automotive industry.

The other participants in the E-diesel project are O2Diesel and RET.

O2Diesel Corp. is a pioneer in the commercial development of E-diesel. The company's product, O2Diesel™, is an ethanol-diesel blend developed using the company's patented and proprietary fuel technology. The introduction is now underway in North America, Brazil, Europe and other global markets. The company has their European office in Seville.

RET, Rotterdamse Elektrische Tram, is the public transport operator in the city of Rotterdam. Besides underground and trams, they operate 238 city buses and have about 190 million passengers every year.

Participants La Spezia site

ATC is the public transport operator in the city of La Spezia. The company has 250 buses and has about 18 million passengers every year.

APRAL, Agenzia Regionale per la Protezione dell'Ambiente Ligure will be responsible for the emissions test.

MAGIGAS Ltd. has been working for 30 years in the sector of the maintenance, planning and installation of fuel, methane and LPG plants. They will blend the fuel.

O2Diesel Corp. will supply the E-diesel additives.

Fuel tank and pump

In Rotterdam a temporary double mantled fuel tank and pump is arranged, which is approved for petrol. The tank is an above ground tank. The Rotterdam site has been given a two year dispensing to use the tank for E-diesel.

In La Spezia a similar tank and pump will be arranged by ATC. The volume of the tank is about 25 000 litres.

Vehicles

The public transport operator RET will test E-diesel on twelve buses. The buses are Euro 3 buses, which has been converted to Euro 5. That is made by installed exhaust gas after treatment, such as SCR and particulate filter.

In La Spezia ATC will provide a small fleet of about 5-10 buses for the demonstration test. The buses are Euro I and Euro II. A few school buses will also be tested.

Emissions test

In Rotterdam the emissions test will be evaluated by TNO. The monitoring will be made with a so called “black box”, which is monitoring the regulated emissions and fuel consumption. The regulated emissions include particulates, nitrogen oxides, hydro carbon and carbon oxide.

In La Spezia the emissions test will be monitored by APRAL. Only the regulated emissions will be measured.

Start of test

Rotterdam expects to start the demonstration test during the first quarter 2008. La Spezia hopes to have all permissions ready so they can start the test in June, 2008.

Further information and results from the E-diesel test will be reported in the final WP3 report.

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